IN THE MATTER OF
Patent Application

CERTIFICATE

I, Yukari NAKAMOTO, residing at 3-13-201, Higashinara 1-chome, Ibaraki-shi, Osaka, Japan, hereby declare that the document attached hereto is a translation made by me of the Japanese Patent Application number **2002-352778** and certify that it is a true translation to the best of my knowledge and belief.

Dated this **21st** day of **October, 2005**

Signature Y. Naka

Yukari NAKAMOTO

[Name of Document] Specification

[Title of the Invention] METHOD FOR FABRICATING SEMICONDUCTOR DEVICE

[Claims]

[Claim 1] A method for fabricating a semiconductor device, the method being characterized by comprising the steps of:

forming an inorganic film on a semiconductor substrate;

forming a resist film containing carbon (C) atoms on the inorganic film;

patterning the resist film;

exposing the patterned resist film to a gas containing sulfur (S) atoms; and

performing dry etching on the inorganic film using the resist pattern as a mask.

[Claim 2] The method for fabricating a semiconductor device of Claim 1, characterized in that the inorganic film is a silicon oxide film, and an etching gas is a fluorocarbon gas.

[Claim 3] The method for fabricating a semiconductor device of Claim 1 or 2, characterized in that the gas containing the sulfur (S) atoms is sulfur dioxide.

[Claim 4] The method for fabricating a semiconductor device of Claim 1 or 3, characterized in that the step of exposing the resist film to the gas containing sulfur (S) atoms and the step of performing dry etching on the inorganic film constitute the same step.

[Detailed Description of the Invention]

[Field of the Invention]

The present invention relates to a method for fabricating a semiconductor device that can prevent resist collapse, which causes pattern abnormality, from being caused in a dry etching process using a resist pattern.

[Prior Art]

Hereinafter, a known method for fabricating a semiconductor device will be described with reference to the drawings.

Figure **3** is cross-sectional views showing process steps for explaining the known method for fabricating the semiconductor device.

First, as shown in Figure **3(a)**, a thermal oxide film **2** and a resist film 3 are formed in this order on a semiconductor substrate **1**, and then the resist film **3** is patterned.

Next, as shown in Figure **3(b)**, dry etching is performed on the thermal oxide film **2** according to the pattern of the resist pattern **103**. For example, when capacitively coupled plasma etching equipment is employed, etching conditions are as follows: CF_4 flow rate is 50 sccm; CHF_3 flow rate is 30 sccm; O_2 flow rate is 5 sccm; the gas pressure is 5Pa; the upper discharge power is 1000W; and the lower discharge power is 1500W.

In recent years, the processing precision of semiconductor devices has become finer, and thus smaller pattern sizes have also been required for resists used for patterning. Therefore, the physical strength of the resists has become smaller (see, for example, patent literature 1). In addition, even when a semiconductor device becomes finer, the thickness of a film to be etched hardly changes. This disables the thickness of a resist to become smaller, in view of the selectivity to the resist at dry etching. Thus, the aspect ratio (the height to the line width) of the resist at pattern formation has been larger.

On the other hand, a dry etching process allows the resist to be etched not only in the vertical direction but also in the parallel direction. This results in the pattern width becoming smaller during etching. Furthermore, influences of heat and ultraviolet radiation coming from plasma used for dry etching cause stresses associated with heat stresses on the resist and degradation in the resist.

Consequently, as the processing precision becomes finer, the resist film **3** is more likely to collapse because of the insufficient strength of the resist film **3** (see, "resist

collapse **5**" in Figure **3(b)**). The resist film **3** that has collapsed during etching serves as an etching mask to prevent etching of a film to be etched underlying the collapsed resist film **3**, resulting in causing a pattern abnormality (see, "pattern abnormality **6** in Figure **3(c)**).

Then, ashing and cleaning processes are performed, thereby removing the resist film **3** as shown in Figure **3(d)**. However, since the pattern abnormal portion **6** is a thermal oxide film, this portion is not removed and remains as it is.

[Patent literature 1]

International Publication Number WO98/32162 pamphlet (Japanese Unexamined Patent Publication No. 10-52239).

[Problems that the Invention is to solve]

As described above, the known method for fabricating a semiconductor device has the problem that the resist film **3** collapses during etching of a film to be processed.

The present invention is made to solve the above problem, and therefore an object of the present invention is to provide a method for fabricating a semiconductor device that realizes a fine pattern without causing resist collapse **5**.

[Means for Solving the Problems]

To solve the above problem, a method for fabricating a semiconductor device according to the present invention includes the steps of: forming an inorganic film on a semiconductor substrate; forming a resist film containing carbon (C) atoms on the inorganic film; patterning the resist film; exposing the patterned resist film to a gas containing sulfur (S) atoms; and performing dry etching on the inorganic film using the resist pattern as a mask.

With this method, the gap containing sulfur (S) atoms is bonded to the sidewalls of the resist pattern during etching of the inorganic film, so that the strength of each of the sidewalls is increased. As a result, a resist collapse is less likely to occur during etching of

the inorganic film.

[Embodiments of the Invention]

(EMBODIMENT 1)

Hereinafter, a method for fabricating a semiconductor device according to a first embodiment of the present invention will be described with reference to Figure **1**.

Figure **1** is cross-sectional views showing process steps of the method for fabricating a semiconductor device according to the first embodiment of the present invention. In Figure **1**, reference numeral **1** denotes a semiconductor substrate, reference numeral **2** denotes a silicon thermal oxide film, reference numeral **3** denotes a resist film, and reference numeral **4** denotes a C-S reaction part.

First, as shown in Figure **1(a)**, the silicon oxide film **2** of an inorganic material and the resist film **3** containing carbon atoms are formed in this order on the semiconductor substrate **1**, and then the resist film **3** is patterned.

Next, as shown in Figure **1(b)**, the silicon oxide film **2** is dry etched using a fluorocarbon gas according to the pattern of the resist film **3**. For example, this dry etching is performed using inductively coupled plasma etching equipment is used under conditions in which the flow rate of CF_4 gas is 50 sccm, the flow rate of CHF_3 gas is 30 sccm, the flow rate of Ar gas is 500 sccm, the flow rate of SO_2 gas is 30 sccm, the whole gas pressure is 5Pa, the upper discharge power is 1000W, and the lower discharge power is 1500W. Now, purposes of the respective gasses will be described. The CF_4 gas and the CHF_3 gas are used as etching gasses for the silicon oxide film **2**. The Ar gas is used as a carrier gas for the etching gas. The SO_2 gas is used to prevent a collapse of the resist film **3**.

The reason why the addition of the SO_2 gas prevents a resist collapse will be described. With respect to the SO_2 gas, when the S component generated from

decomposition of the SO_2 gas with plasma comes to be in contact with the resist film **3**, the S component bonds to carbon (C) which is a component of the resist film **3** in the form of C-S to be attached to the sidewalls of the resist film **3**. The thus-formed C-S reaction part **4** protects the sidewalls of the resist film **3** and increases the strength of the resist film **3**. Accordingly, a resist collapse is suppressed.

On the other hand, the silicon oxide film **2** hardly reacts with sulfur. Therefore, etching of the silicon oxide film **2** is not prevented.

Next, as shown in Figure **1(c)**, the resist pattern **3** is removed through ashing and cleaning processes.

Thereafter, the semiconductor device is completed in the usual manner.

In this embodiment, the silicon oxide film **2** is used as a film to be etched. Alternatively, silicon oxide film such as a TEOS film and BPSG film, a silicon nitride film, a silicon oxynitride film, polysilicon and amorphous silicon may be used. In such cases, similar advantages to those of this embodiment are obtained.

A SO_2 gas described is used in patent literature 1 because the SO_2 gas is capable of etching an organic antireflection material to be etched. In a case where the silicon oxide film **2** which cannot be etched with the SO_2 gas is used as a film to be etched as this embodiment, the SO_2 gas used in patent literature 1 cannot be employed as an etching gas.

In addition, CF_4 and CHF_3 are used for etching gasses. Alternatively, other etching gasses may be used.

(EMBODIMENT 2)

Hereinafter, a method for fabricating a semiconductor device according to a second embodiment of the present invention will be described with reference to Figure **2**.

Figure **2** is cross-sectional views showing process steps of the method for fabricating a semiconductor device according to the second embodiment of the present

invention. In Figure **2**, reference numeral **1** denotes a semiconductor substrate, reference numeral **2** denotes a silicon thermal oxide film, reference numeral **3** denotes a resist film, and reference numeral **4** denotes a C-S reaction part.

First, as shown in Figure **2(a)**, the silicon oxide film **2** of an inorganic material and the resist film **3** containing carbon atoms are formed in this order on the semiconductor substrate **1**, and then the resist film **3** is patterned.

Next, as shown in Figure **2(b)**, SO_2 gas plasma is applied onto the surface of the semiconductor substrate **1**. For example, this plasma application is performed using capacitively coupled plasma etching equipment under conditions in which a flow rate of SO_2 gas is 50 sccm, the gas pressure is 1Pa, the upper discharge power is 200W, and the lower discharge power is 30W. At this time, the S component generated from decomposition of the SO_2 gas with plasma bonds to C which is a component of the resist **4** in the form of C-S to be attached to the sidewalls of the resist film **3**. The thus-formed C-S reaction part **4** protects the sidewalls and increases the strength of the resist film **3**. On the other hand, the silicon oxide film **2** hardly reacts with S, so that S is hardly attached to the surface of the silicon oxide film **2** and does not affect a dry etching process of the silicon oxide film **2**, which will be described below.

Next, as shown in Figure **2(c)**, the silicon oxide film **2** is dry etched using a fluorocarbon gas according to the pattern of the resist film **3**. The fluorocarbon gas is made of, for example, CF_4 or CHF_3. At this time, the sidewalls of the resist film **3** is already protected by the C-S reaction part **4**, so that etching is performed without a collapse of the resist film **3**.

Then, as shown in Figure **2(d)**, the resist film **3** is removed by ashing and cleaning processes.

Thereafter, the semiconductor device is completed in the usual manner.

With the method for fabricating a semiconductor device according to the first embodiment, the strength of the resist pattern **3** is increased, so that a resist collapse is prevented and the silicon oxide film **2** is etched into a desired shape.

[Effects of the Invention]

As described above, the present invention provides a method for fabricating a semiconductor device capable of forming a fine pattern with stability without occurrence of pattern abnormality due to resist collapse in a process step of processing the fine pattern by dry etching.

[Brief Description of the Drawings]

[Figure **1**]

Cross-sectional views showing process steps of a method for fabricating a semiconductor device according to a first embodiment of the present invention.

[Figure **2**]

Cross-sectional views showing process steps of a method for fabricating a semiconductor device according to a second embodiment of the present invention.

[Figure **3**]

Cross-sectional views showing process steps of a conventional method for fabricating a semiconductor device.

[Description of the Reference Numerals]

1	semiconductor substrate
2	silicon thermal oxide film
3	resist film
4	C-S reaction part
5	resist collapse
6	pattern abnormal portion

[Name of Document] Abstract

[Abstract]

[Purpose] An object of the present invention is to provide a method for fabricating a semiconductor device enabling processing of a fine pattern without occurrence of a resist collapse.

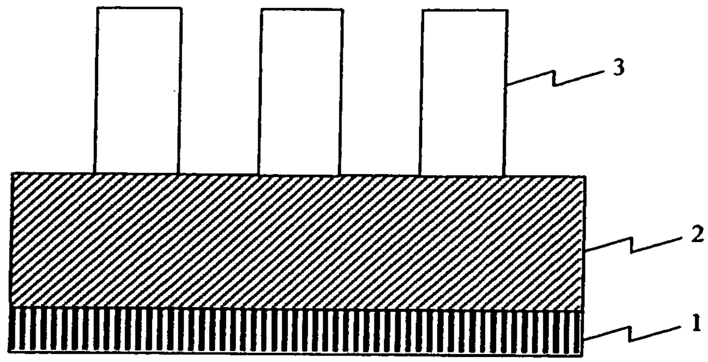
[Solution] Provided are the steps of: forming an inorganic film **2** on a semiconductor substrate **1**; forming a resist film **3** containing carbon (C) atoms on the inorganic film **2**; patterning the resist film **3**; exposing the patterned resist film **3** to a gas containing sulfur (S) atoms; and performing dry etching on the inorganic film **2** using the resist pattern **3** as a mask.

[Selected Figure] Figure **1**

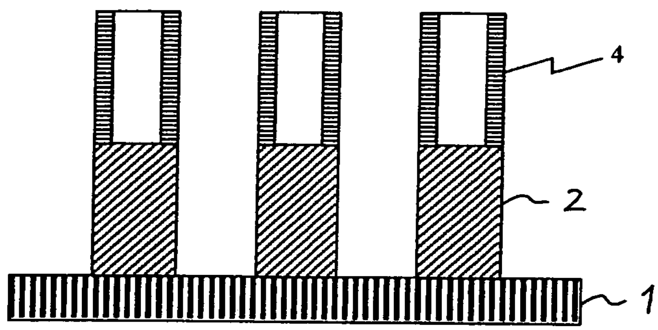
【書類名】　図面 [Name of the Document] Drawings

【図１】
[Figure 1]

(a)



(b)



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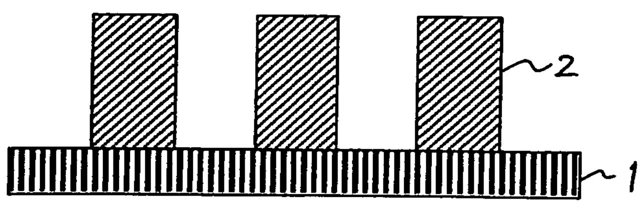


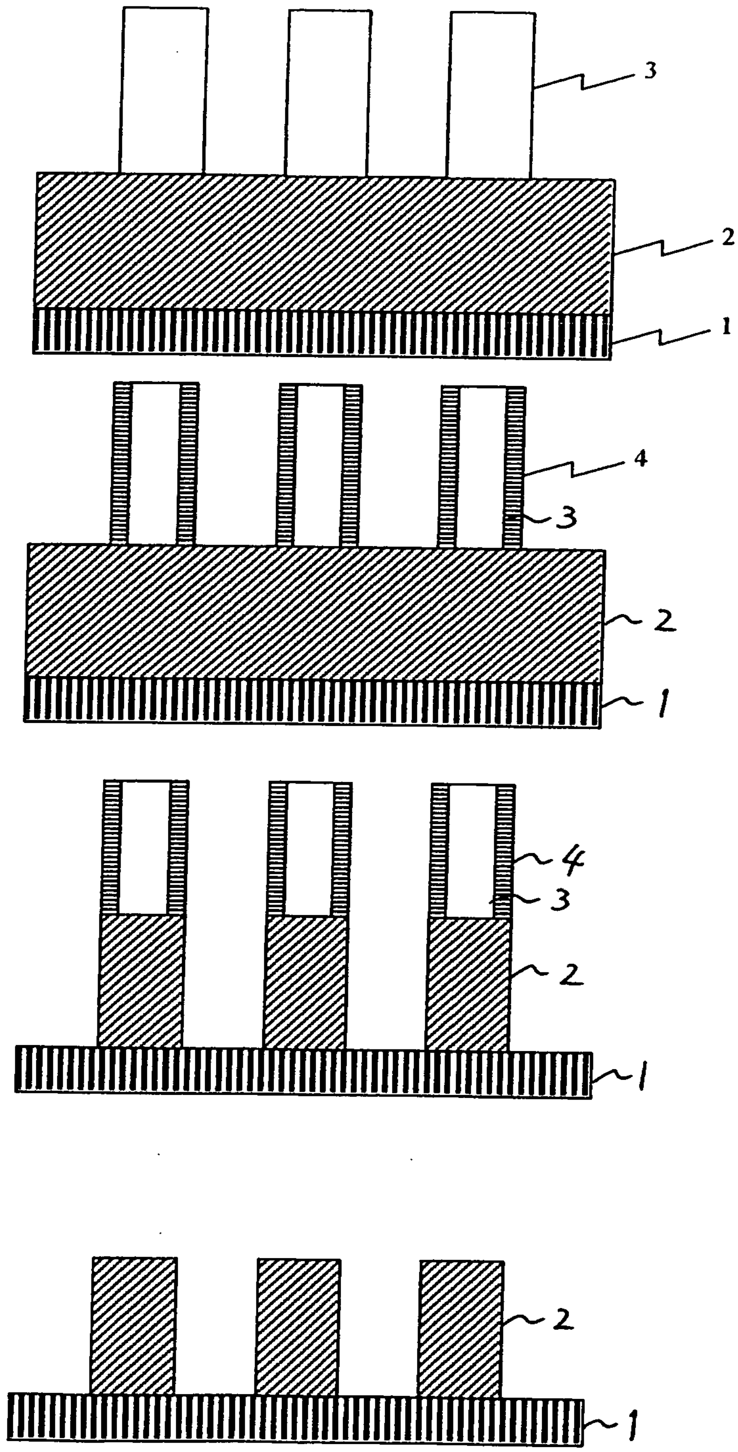
【図２】[Figure 2]

(a)

(b)

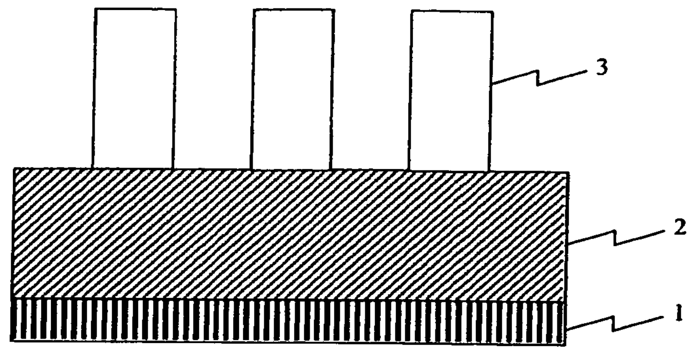
(c)

(d)



【図３】
[Figure 3]

(a)



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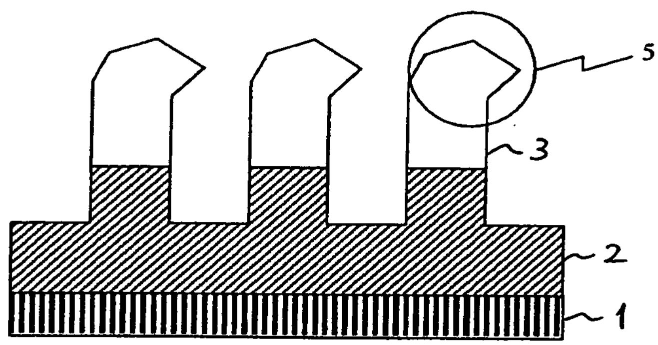

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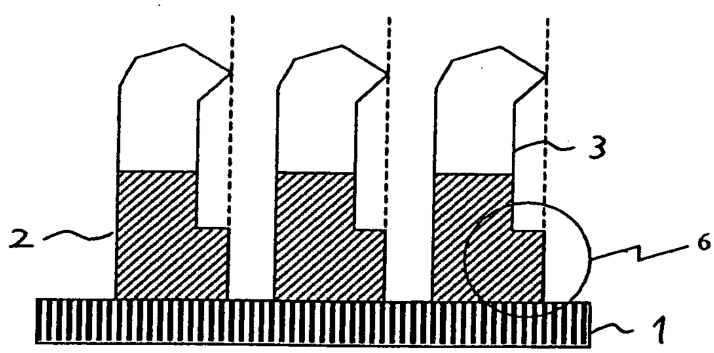

(d)